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Lunar Ice Cube: Determining Volatile Systematics Via Lunar Orbiting Cubesat

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Abstract

We have applied the CubeSat Paradigm to science requirements-driven deep space exploration mission, Lunar Ice Cube, and are developing a compact 'workhorse' instrument for a high priority science application, which has just been selected for the HEOMD NextSTEP program for EM1 launch. Lunar Ice Cube complements Lunar Flashlight, a mission previously selected for EM1, by focusing on the abundance, location and transportation physics of water forms and components on the lunar surface at a variety of latitudes and terminator crossings not restricted to Permanently Shadowed Regions.

1. Introduction

We focus on measurement of lunar volatiles because of their apparently important role, based on recent lunar orbital measurements (1-9), with implications for environmental processes on the atmosphereless bodies that account for most of the surface area in the solar system. In addition, the Moon's accessibility as a stepping stone to the rest of the solar system, combined with its suitability as an analog with extreme range of conditions and thus an ideal technology testbed for much of the solar system, make it an ideal candidate for exploration. The recent announcements of opportunities to propose to fly cubesats on EM1 (e.g., NASA NextSTEP BAA, NASA SIMPLEx NRA) have generated a plethora of proposals for 'lunar cubes'.

2. Payload and Spacecraft Descriptions

Over the course of this year, we have conducted the equivalent of a pre-phase A study for a lunar orbital mission with a focus on the payload instrument. Subsystems required for deep space operation include state of the art active cubesat attitude control, propulsion (for transportation from GEO, GTO or Earth escape to lunar capture), communication, power, thermal and radiation protection systems providing lunar orbital operation of a cubesat bus. Based on this work, we have concluded that a 6U bus with state of the art cubesat systems already available or now being built and tested can support a high priority science orbiter in cislunar space. Particular challenges for lunar cubesats are remote communication, navigation and tracking, thermal and radiation protection in a volume, power, and bandwidth constrained environment.

Despite the fact that 6U deep space capable cubesat buses and deployers are now available, the development of CubeSat instruments capable of providing focused, high priority science, so critical to achieving the potential for low cost planetary exploration promised by the CubeSat paradigm, has evolved more slowly. A major challenge is the development of compact yet sufficiently robust and sensitive versions of successful instruments in a 'funding starved' environment. In response to both of these challenges, we are developing BIRCHES, Broadband InfraRed Compact, High-resolution Exploration Spectrometer, a miniaturized version of OVIRS on OSIRIS-REx a compact version of the successful volatile-seeking GSFC-designed OSIRIS Rex OVIRS leveraging extensive heritage and previous work on its components. BIRCHES is a compact (1.5U, 2 kg, <5W) point spectrometer with a compact cryocooled HgCdTe detector for broadband (1 to 4 micron) measurements at sufficient resolution (10 nm) to characterize and distinguish important volatiles (water, H_2S, NH_3, CO_2, CH_4, OH, organics) and mineral bands. It has built-in flexibility, using an adjustable 4-sided iris, to maintain the same spot size regardless of variations in altitude (by up to a factor of 5) or to vary spot size at a given altitude, as the application requires.

Lunar Ice Cube will be developed and managed by Morehead State University and include radiationhardened subsystems, GSFC designed payload thermal protection system, the JPL Iris transceiver, a high power solar panel/actuator system and a robust multiple-processor based payload processor. The Busek Iodine-based Ion Drive will provide propulsion necessary to achieve the science orbit from EM-1 release. GSFC Flight Dynamics will manage and execute trajectory modeling and navigation.

3. Science Measurements

BIRCHES will provide IR spectral measurements of major forms and components of volatiles, including the entire 3 um region associated with water ice and hydroxyl, to 1) reveal water and other volatiles distribution as a function of time of day, latitude, and terrain; 2) provide a geological context for those measurements through simultaneous spectral determination of mineralogical composition, and maturity; and 3) expand understanding of volatile sources, sinks, and processes with implications for the distribution, abundance, origin, and evolution of lunar and other atmosphereless bodies, surfaces and interiors.

4. Conclusions

Lunar Ice Cube addresses the broad strategic objectives of advancing understanding of solar system formation and evolution, and interaction and evolution of chemical and physical processes on the Moon, and by implication other small atmosphereless bodies, surfaces and interiors, by establishing the basis of intriguing evidence for surface volatiles, cold traps, and 'wetter' interiors from previous missions (1-9). In particular, we address the question: What governed the accretion, supply of water, chemistry, and internal differentiation of the inner planets and the evolution of their atmospheres, and what roles did bombardment by large projectiles play? Lunar Ice Cube augments, complements, provides a context for, and utilizes measurements from previous (Chandrayaan, LCROSS, LRO, LADEE) and planned (Lunar Flashlight) missions by capturing the 'systematics' of volatile form and component distribution, defined as their specific character and abundance (OH versus H_2O as ice or various forms of bound water and other volatiles) as a function of surface temperature (diurnal variation and average), illumination geometry (latitude and average slope), particle exposure, and regolith character. Lunar Ice Cube will thus provide input crucial for understanding the role of external sources, internal sources, solar wind proton and micrometeorite bombardment in formation, trapping, and release of water and exosphere formation.

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